**Transitioning to biomass fuels in general aviation**

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After having proven the concept of ethanol as an aviation fuel for piston engine aircraft, RAFDC is now working toward FAA certification of the most popular General Aviation aircraft on all blends of the existing aviation gasoline (avgas), 100% denatured ethanol and ETBE.

Avgas is the last fuel in the United States containing lead. The aviation industry has been put on notice that they must soon replace avgas with an unleaded fuel. Certification of aircraft on all blends of avgas, ethanol and ETBE will permit an orderly transition from fossil fuels to biomass fuels. The use of all blends will allow aircraft to use any fuel available at an airport during the transition period.

The objectives of the RAFDC program are:

1. To determine performance, emissions, and fuel characteristics of blends of 100 % denatured ethanol, ETBE and 100LL and compare their performance, emissions and fuel characteristics.
2. To address technical concerns in regard of ethanol's chemical properties and its blending characteristics.
3. To evaluate the quality control system in place for ethanol and to propose a model distribution system at airports.

**Urgency**

General Aviation, in the United States and in the world, is facing the demise of lead as an octane booster in its most commonly used fuel, 100LL. There is a crucial need to develop an unleaded high-octane fuel for general aviation. Ethanol and ETBE are promising candidates. Concerns arising from the future use of these fuels and their blending characteristics with 100LL are to be addressed. With ethanol and ETBE distributed at airports, the potential for pressures in the field to blend two or all three of these fuels (assuming 100 LL will be available for few more years), makes it imperative to study the technical characteristics of the various possible combinations. The use of fuel blends, if proved safe, would provide great flexibility from both a supply and an economic standpoint.

This investigation program assumes a phase-in period of ethanol and/or ETBE in the marketplace. The time period, with dual refueling infrastructure, would allow for an orderly transition from Avgas to ethanol (and/or ETBE). Any aircraft properly modified could choose to use either ethanol, ETBE or avgas in any concentrations when operating either in their home base area or when traveling throughout the country. Thus, there would be no decrease in mobility or ease of operation, and in fact given the current circumstances and the most likely future situation, the use of ethanol and ETBE would result in cost saving both at the pump and in operational costs. It would be very cost effective for an aircraft owner or fleet operator to wait until it is time to overhaul the aircraft engine to perform simple and inexpensive modifications in order to use either ethanol, ETBE or avgas or any combination of the three.

**The case for ethanol and ETBE in a transition phase**

RAFDC has obtained the first FAA Supplemental Type Certificates (STCs) for the use of 100%-denatured ethanol. A considerable spectrum of the general aviation type aircraft has been tested: high wing type aircraft with carbureted engines, and low wing type aircraft with injected engines. As already proved during previous programs, maximum power available on both ethanol and ETBE was greater than Avgas with ethanol providing the greatest increase (between 10 to 20% increase over Avgas).

Environment: Emissions tests results were compared. Test results clearly show that ethanol and ETBE not only have the advantage of being lead free, high-octane fuels, producing more power than Avgas, but also are more environmentally friendly, adding very little to the greenhouse gas burden.

Secure supply: In 1973, the Unites States was subjected to its first major fuel supply interruption by the Arab Oil Embargo. At that time oil imports in the U.S. represented approximately 37% of the domestic annual oil consumption. Congress debated then, among other measures, cutting off or rationing fuel to general aviation. Today, the U.S. imports over 60% of its petroleum, considerably increasing the vulnerability of the country to fuel disruptions. To develop domestically produced transportation fuels is the only rational course of action to pursue in order to secure the country's energy independence and the long term survival of general aviation. There is virtually limitless supply of feedstock available to produce ethanol.

Economics: The cost of Avgas varies considerably, but it is, currently, at least 50 cents per gallon more than ethanol and in some cases even more than that. Engine endurance tests showed considerably less wear on ethanol than on avgas. Consequently, it is estimated that the Time Between Overhaul (TBO) in an engine on ethanol could easily be extended by 100% over avgas. This would represent a considerable saving in operational costs. Lead will soon be unavailable as an octane enhancer, and any replacement, other than ethanol, with adequate octane, will be at least as expensive and in all probability more expensive, increasing the cost of a future fuel at the pump. At the current prices and at the existing state of technology, the economics of ethanol used as an aviation fuel are already competitive.

In the United States, the current production of ethanol is approximately 4 times the annual consumption of aviation gasoline. Thus, general aviation is a perfect niche market for ethanol, and the economics are a good match at this time, and will improve in ethanol's favor over the near future.

Testing of blends of ethanol, ETBE and Avgas: A realistic transition phase from fossil fuels to biofuels will have to include the use of the currently used avgas. The initial implementation scenario has to consider blends of these fuels. The flights to and from the locations where aerobatic demonstrations on ethanol have been performed in the past two decades (all over the United States), have been flown on every conceivable blend of ethanol, ETBE and Avgas. In all of these flights, there has never been an engine problem associated with the use of these blends.

Test cell and flight testing are used to collect baseline data on 100LL, ethanol and ETBE and their blends. This paper will report on ground and flight tests, analysis of water absorption and investigations on quality control and distribution systems of ethanol and ETBE.

There is general agreement in the aviation community today that the lead will come out of the currently used aviation gasoline. The issue is "when". The development of an environmentally compatible as well as economic unleaded aviation fuel is a urgent matter. Ethanol and ETBE have been proven by RAFDC to be outstanding replacement fuels for general aviation.